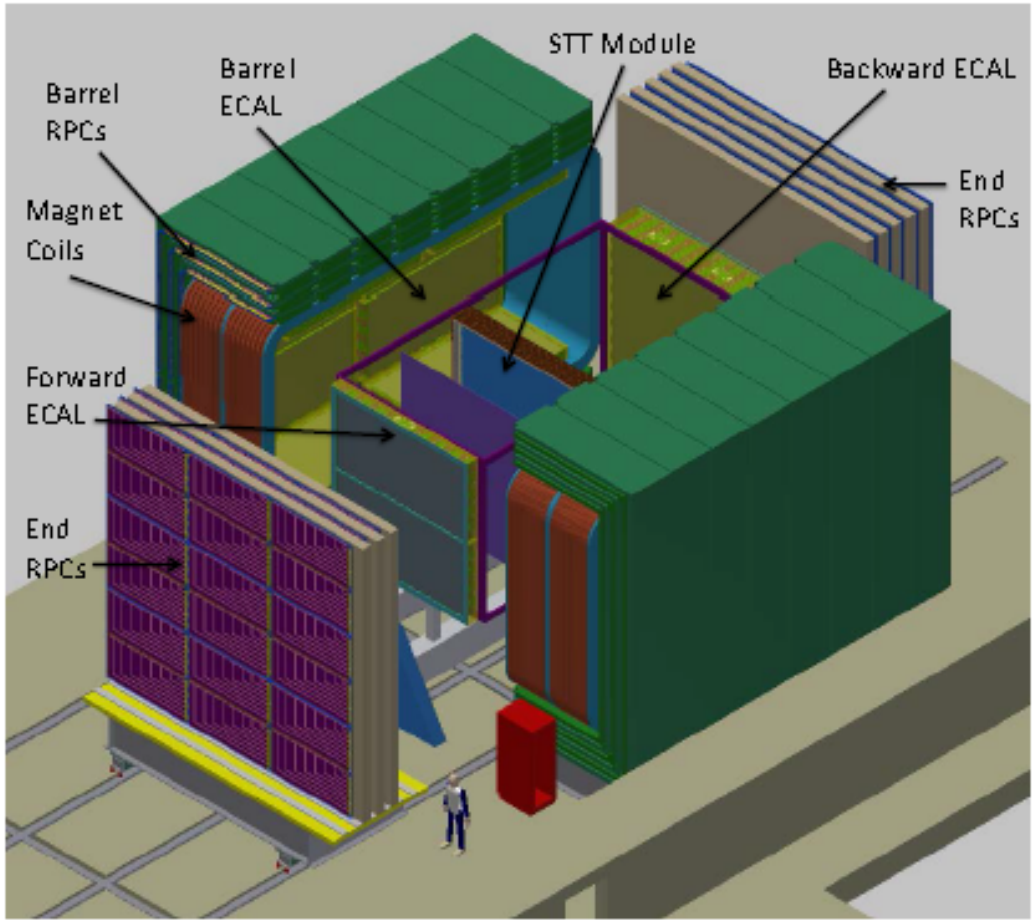
Electromagnetic Calorimeter: R & D and Prototyping

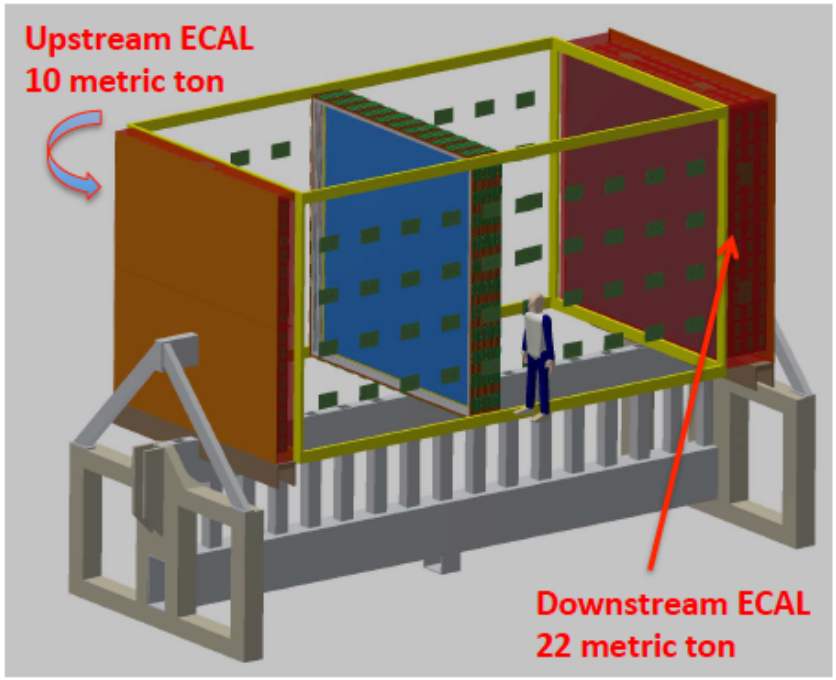
Bipul Bhuyan
Indian Institute of Technology Guwahati

DUNE Near Detector Working Group Meeting

September 24, 2015

DUNE Near Detector





DUNE Near Detector ECAL

The 4π lead-plastic scintillator electromagnetic calorimeter has three components:

- **Downstream ECAL**: 58 layers of alternating horizontal/vertical extruded plastic scintillator strips per 1.75 mm of lead along the z-direction. The dimension of each scintillator bar is 4 m x 2.5 cm x 1 cm. 160 bars per layer and 9280 scintillator bars in total.. Two sided readout via extruded WLS fiber and SiPM. **18 radiation length in total**.

Fully contained EM shower in the Downstream ECAL.

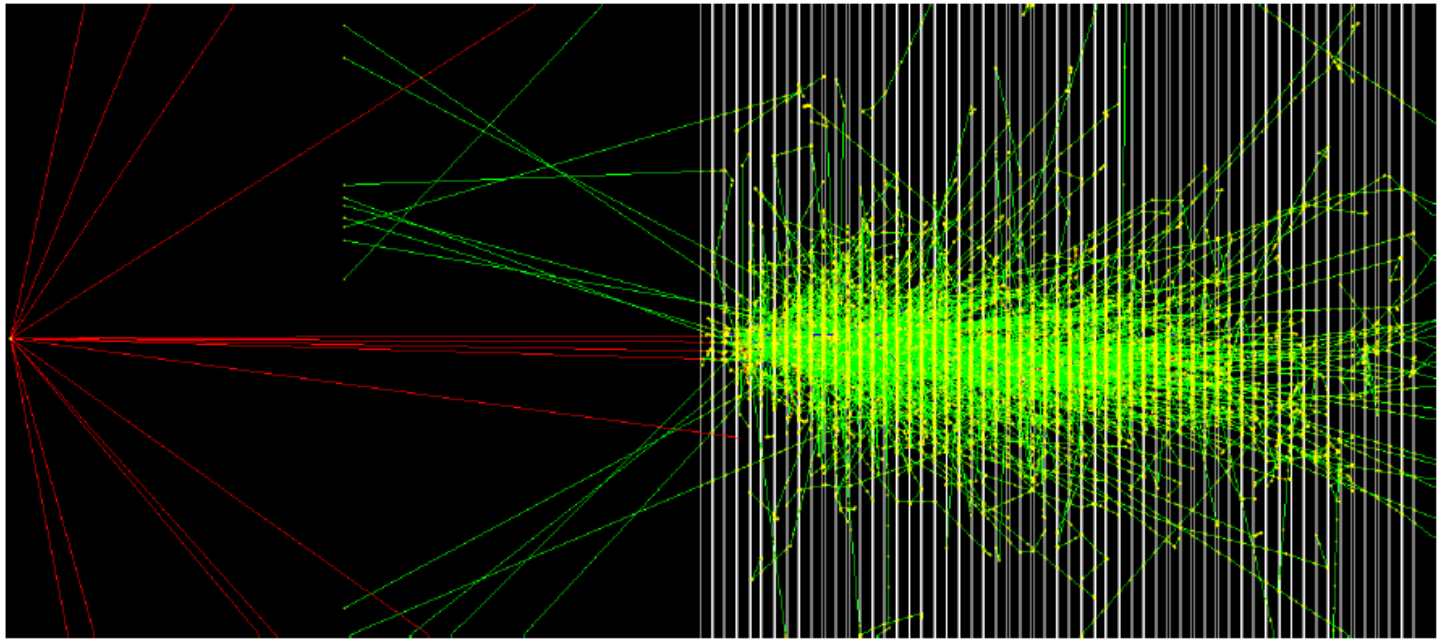


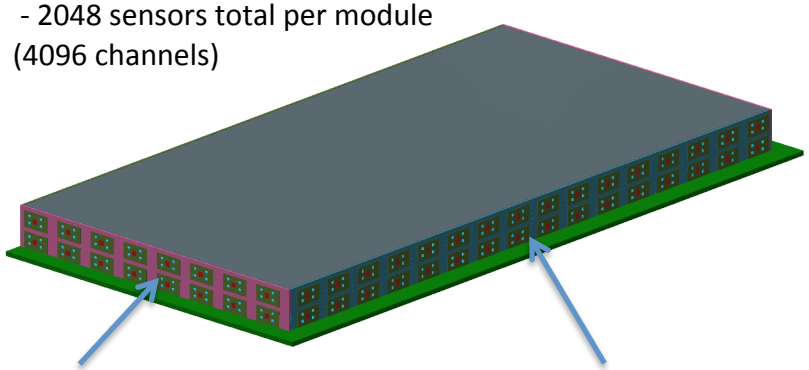
Figure : Longitudinal view of the electromagnetic shower in the Downstream ECAL by 2 GeV electrons (10,000 events)

DUNE Near Detector ECAL

The 4π lead-plastic scintillator electromagnetic calorimeter has three components:

- **Barrel ECAL**: Will surround the sides of the STT. Total 16 modules with each module containing 16 layers of alternating horizontal/vertical strips per 3.5 mm Pb**. 10 radiation length in thick.**
- **Upstream ECAL**: Similar to one of the Barrel-ECAL module. 16 layers of alternating horizontal/vertical scintillator strips per 3.5 mm Pb along the z-direction. **10 radiation length**.

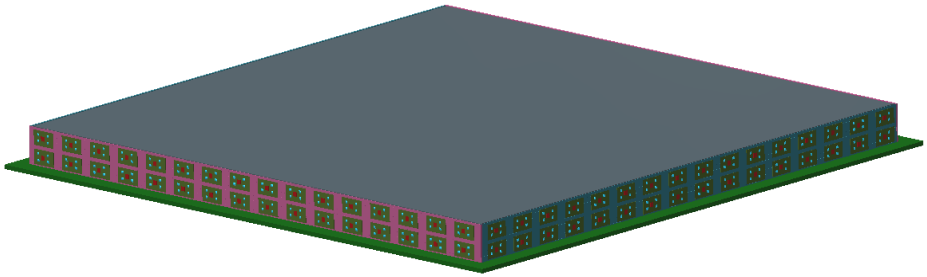
Barrel ECAL module
- 1980mm x 3900mm
- 2048 sensors total per module (4096 channels)



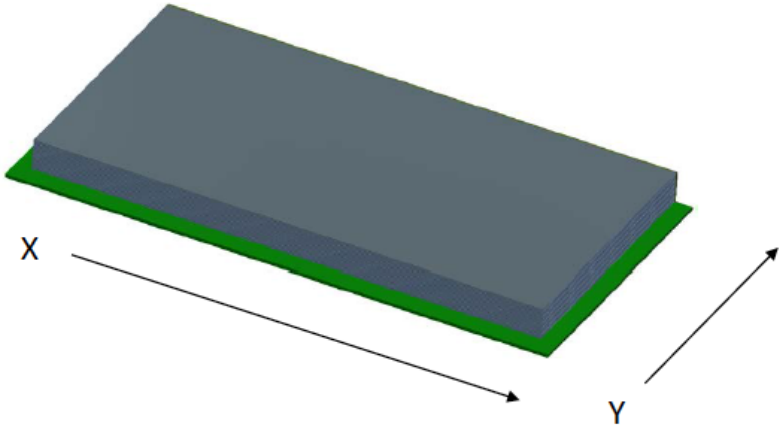
512 sensors – 1024 channels per end

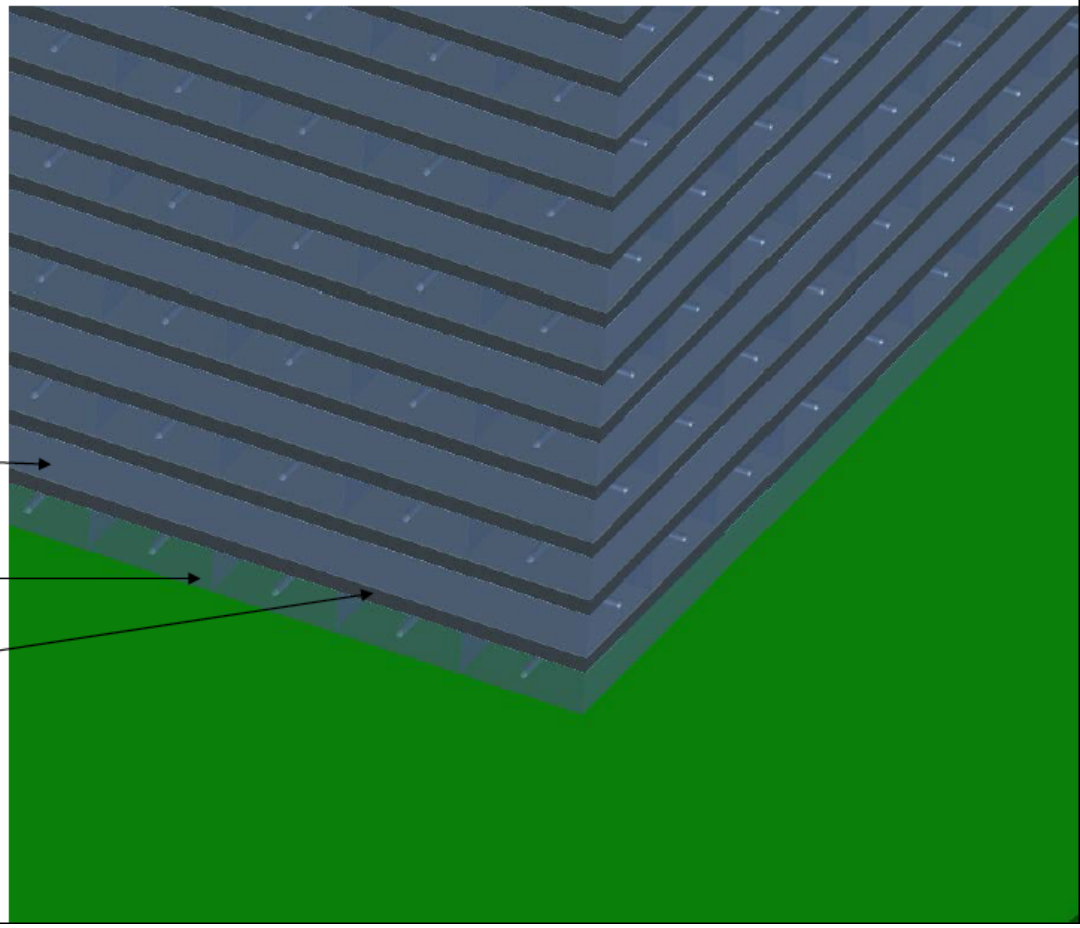
1024 sensors – 2048 channels

Upstream or Backward ECAL module
- 3900 mm x 3900 mm
- 4096 sensors total (8192 channels)



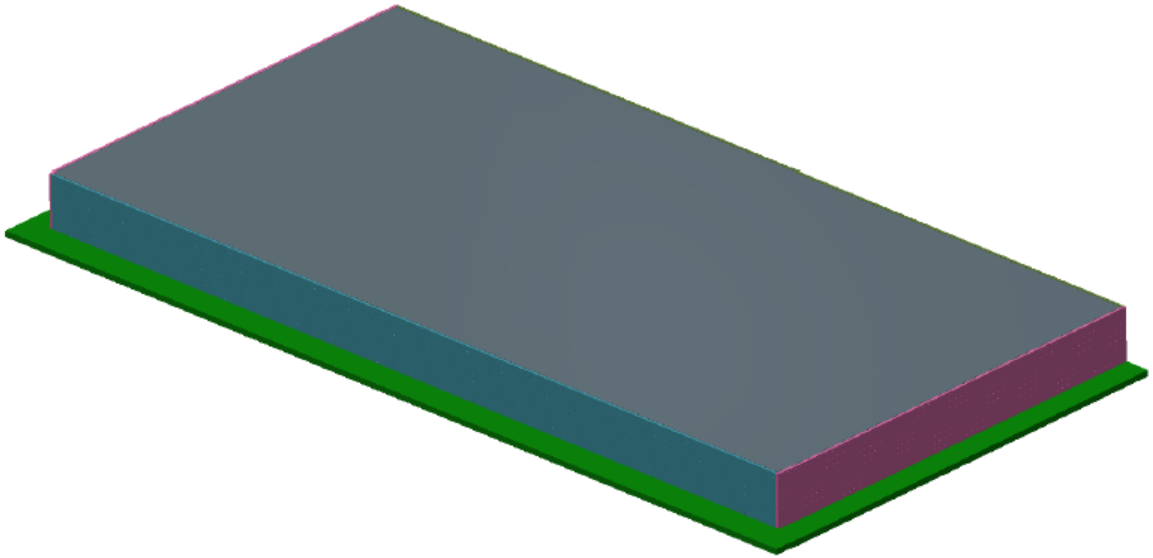
Barrel Module Assembly

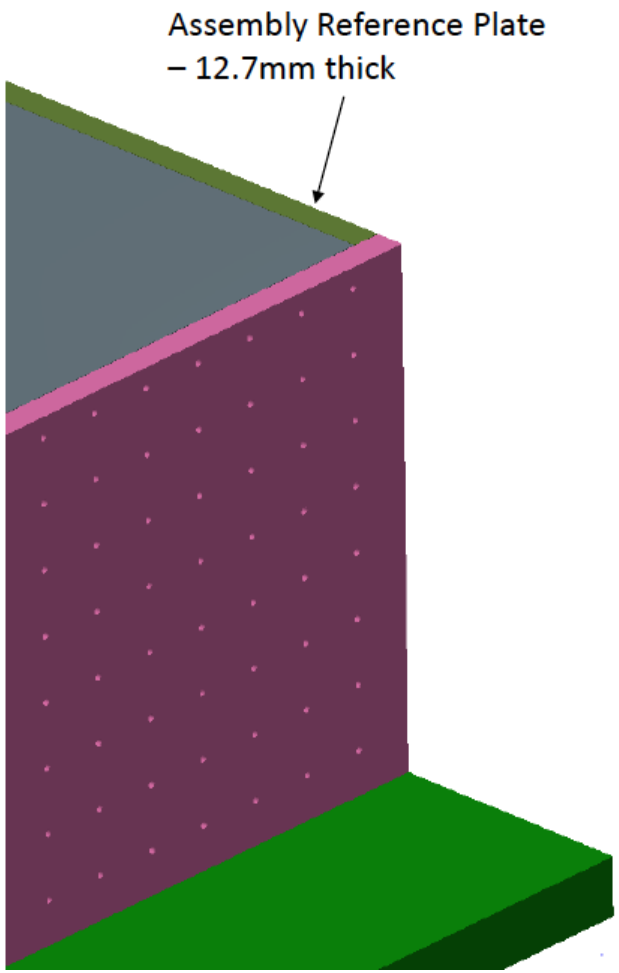




Jan Boissevain

Barrel Module Assembly





Barrel ECAL module Assembly:

- Need space for electronics and services (cooling for electronics, cabling etc.). Current assumption is about 10 cm
- Minimize electronics=> limited space in the Barrel region.
- For Barrel ECAL modules, possibly mirror one end (shorter) of the WLS fiber.

Jan Boissevain

ECAL Specifications

Item	Specification
Scintillator Bar Geometry	**4 m x 2.5 cm x 1 cm**
Number of Forward ECAL Scintillator Bars	9280
Forward ECAL Pb thickness	1.75 mm
Number of Forward ECAL Layers	58
Number of Forward ECAL Radiation Lengths	18
Dimensions of Forward ECAL Module	4 m $\times$ 4 m $\times$ 45 cm
Number of Barrel ECAL Scintillator Bars	20,480
Barrel ECAL Pb thickness	3.5 mm
Number of Barrel ECAL Layers	16
Number of Barrel ECAL Radiation Lengths	10
Number of Barrel ECAL Modules	16
Dimensions of Barrel ECAL Modules	4 m $\times$ 2 m $\times$ 15 cm
Number of Backward ECAL Scintillator Bars	2,560
Backward ECAL Pb thickness	3.5 mm
Number of Backward ECAL Layers	16
Number of Backward ECAL Radiation Lengths	10
Dimensions of Backward ECAL Module	4 m $\times$ 4 m $\times$ 15 cm
Total Length of 0.7mm Diameter WLS Fiber	129.3 km
Total Number of Scintillator Bars	32,320
Total Number of Electronics Channels	64,640
Total Mass of Scintillator	16,160 kg
Total Mass of Pb	110,000 kg

DUNE Near Detector ECAL

The electromagnetic calorimeter will be designed and constructed in two phases:

- **R & D and Prototyping Phase (3 yrs):**
  - **Construct a 2 m x 2 m downstream ECAL with about 10 radiation length.**
  - **Participating Institutions: IIT Guwahati, Delhi University and Bhabha Atomic Research Centre (BARC), LANL**
- **Final ECAL design and assembly (4 yrs)**
  - **Assembly hall for the final ECAL will be setup at IIT Guwahati during the prototyping phase.**
- **The plan is in accordance with the DPR submitted to the Department of Atomic Energy and Department of Science and Technology, India.**
  - **The execution of this project is subject to release of the requested fund.**

R & D and Prototyping of the Downstream ECAL

Build a half scale downstream ECAL as a prototype: 2 m x 2 m in size and 10 radiation length deep.

- **Steps for the DS-ECAL prototyping:**
  - Procure materials such as, scintillator bars, WLS fibers, SiPM, Pb sheets, epoxy adhesive etc.
  - Setting up QA mechanism for the scintillator bars, fibers and Pb sheets.
  - Setting up tools for the evaluation of the SiPM.
  - Assemble scintillator bars in an Al frame to form a layer, lay the Pb sheet on top of the scintillator bar layer.
  - Insert the WLS fiber (Kuraray fiber) into the bars, connect the fibers to the SiPMs. Fiber diameter (1 mm ?) to be decided after a detail study on the light output.
  - Setup 2D scanning device to scan the longitudinally and transversely assembled layer with a radioactive source.
  - Detail R & D on the coupling of the fiber with the SiPM and the coupling of the fiber with the scintillator material.
  - Develop readout electronics in association with BARC. Put the prototype in a cosmic test stand with full DAQ before testing the prototype in a test beam.

Laboratory Infrastructure for the ECAL assembly

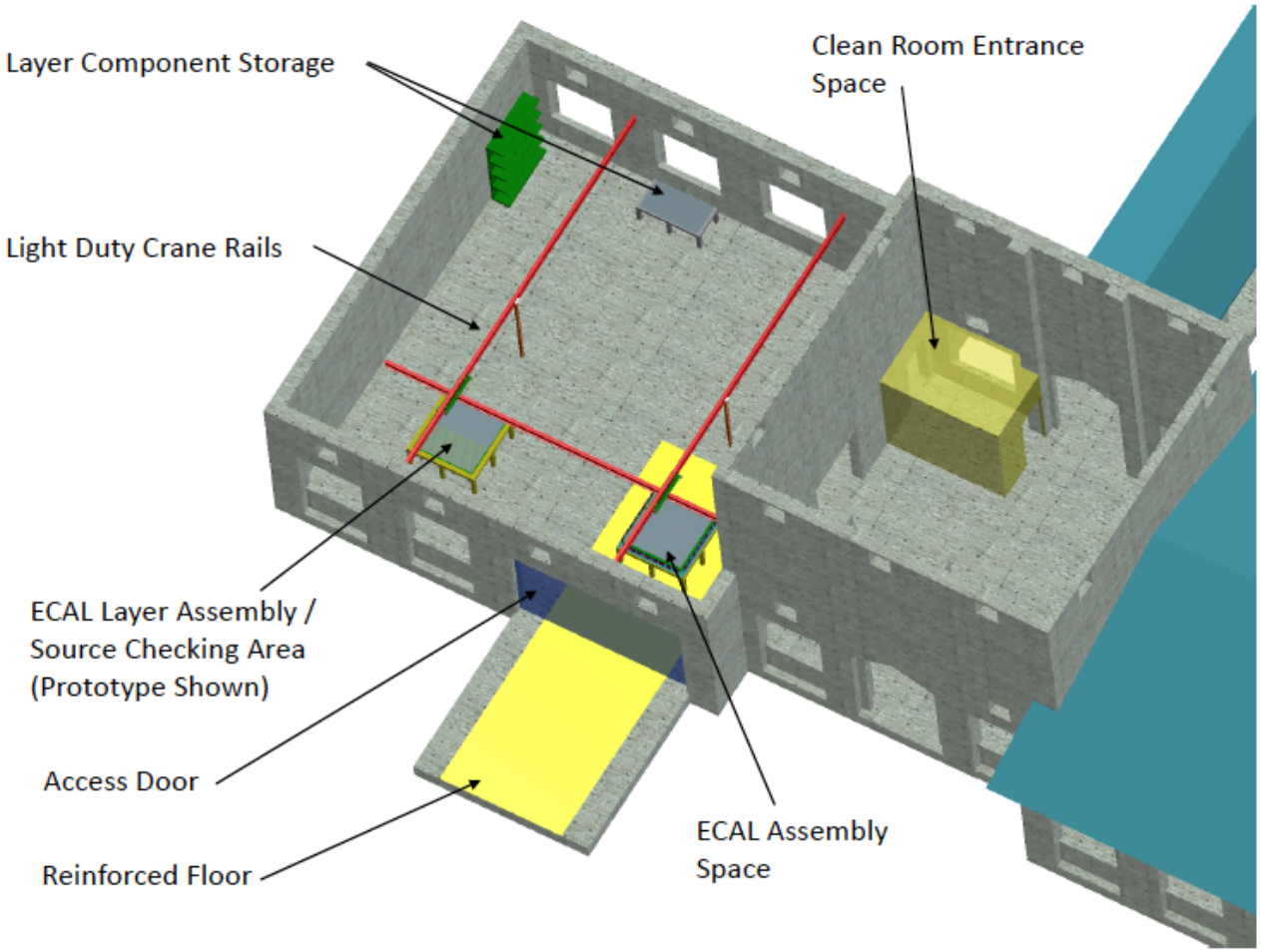
At IIT Guwahati, a laboratory space of dimensions **32 m x 12 m** is already identified:

- Laboratory infrastructure needs to be developed for the R & D work as well as for final layer and module assembly.
  - Current focus is on designing a class 10,000 clean room with the necessary hydraulic crane infrastructure in it.

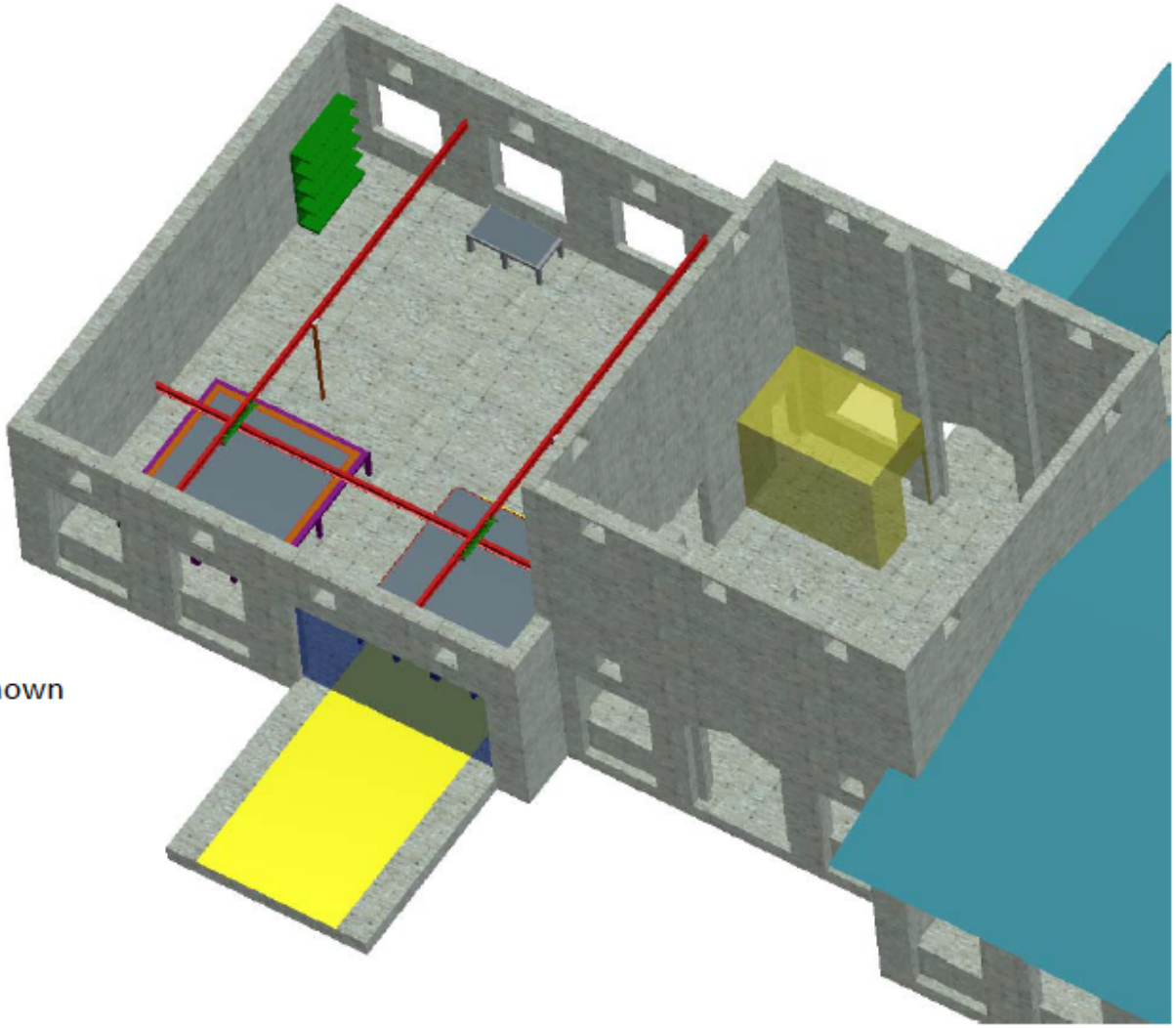
One of the side rooms will be used for detector assembly while the other will be used for material Storage and QA etc.

Laboratory Infrastructure for the ECAL assembly

Class 10,000 clean room design at IIT Guwahati for 12 m x 12 m lab space:



Laboratory Infrastructure for the ECAL assembly

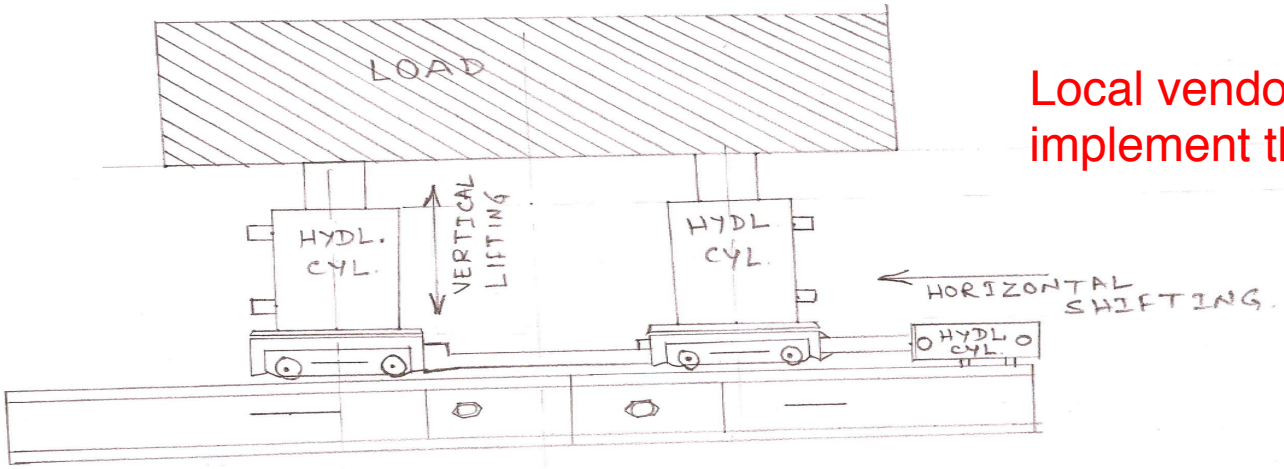


Forward ECAL shown

Laboratory Infrastructure: Issues to be addressed

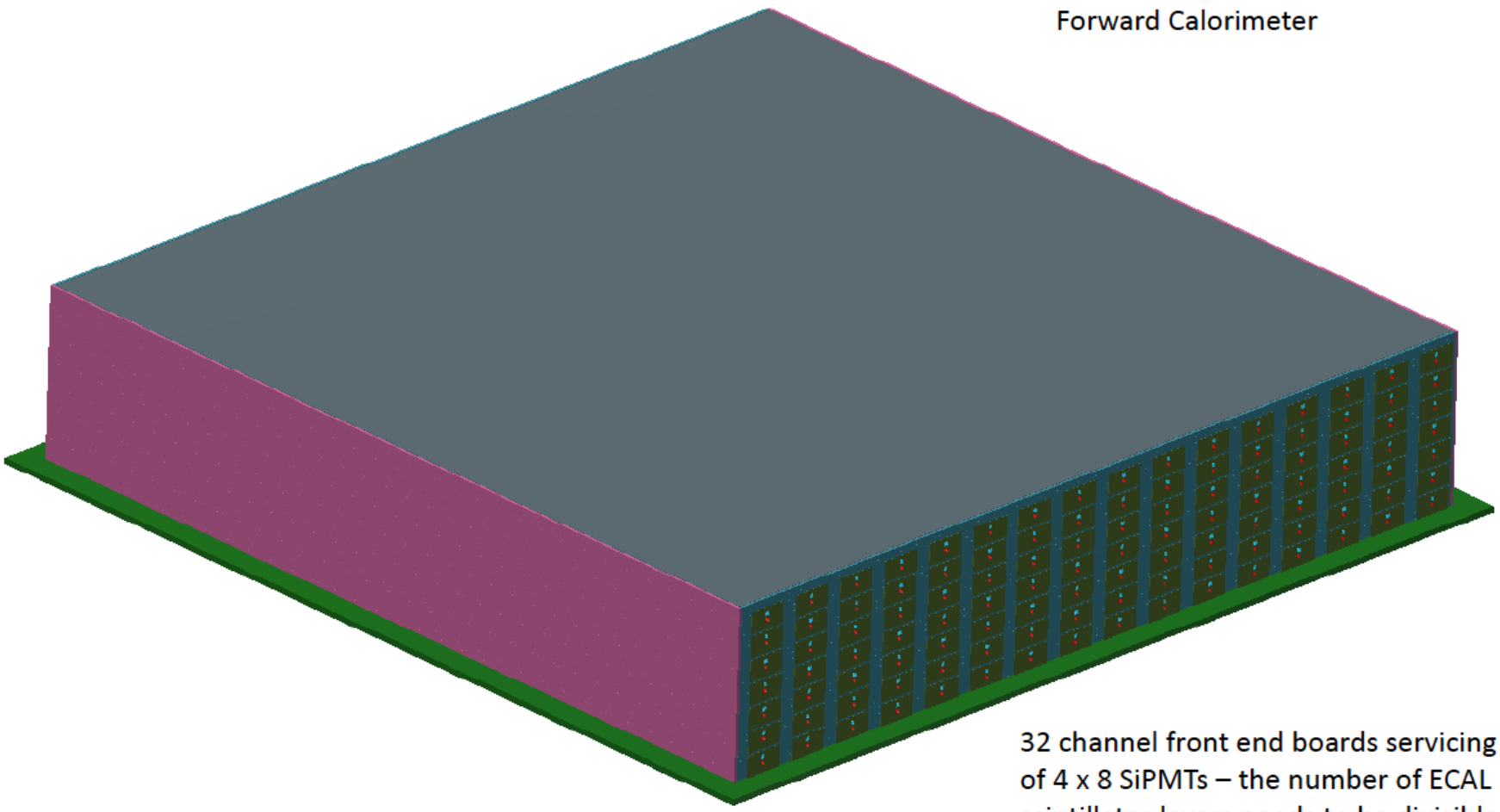
- Need to decide size/design of the final downstream ECAL: 4 m x 4 m or alternatives?
  - ✓ Stability of the 4 m x 4 m structure?
  - ✓ Alternate design: Two 4 m x 2 m downstream ECAL?
    - ✓ Downside: Dead space in the DS-ECAL, one sided readout in the shorter dimension!
    - ✓ Require a detail Geant simulation to understand the performance of any alternate desig
- Handling the weight of the DS-ECAL

  – DS-ECAL will weigh about 22 metric ton. I-beam on the existing wall will not be able to support such weight.



Local vendor is identified to implement the design.

ECAL Readout Electronics Concept

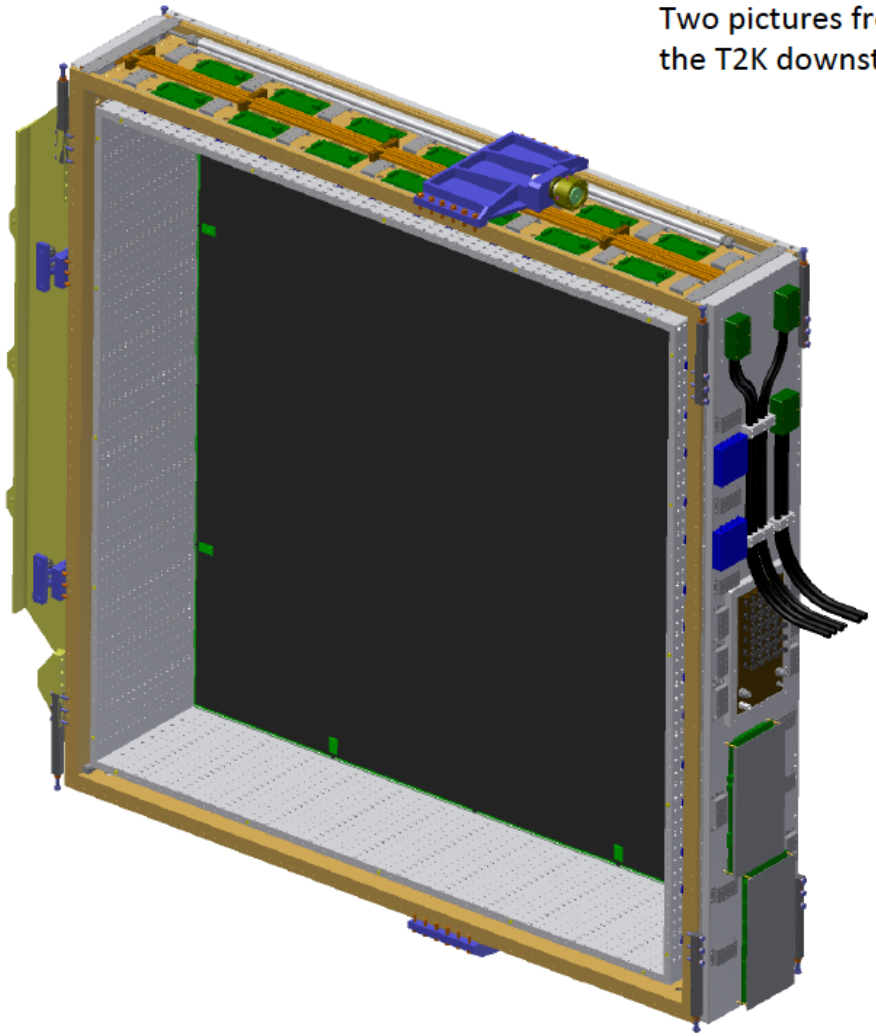


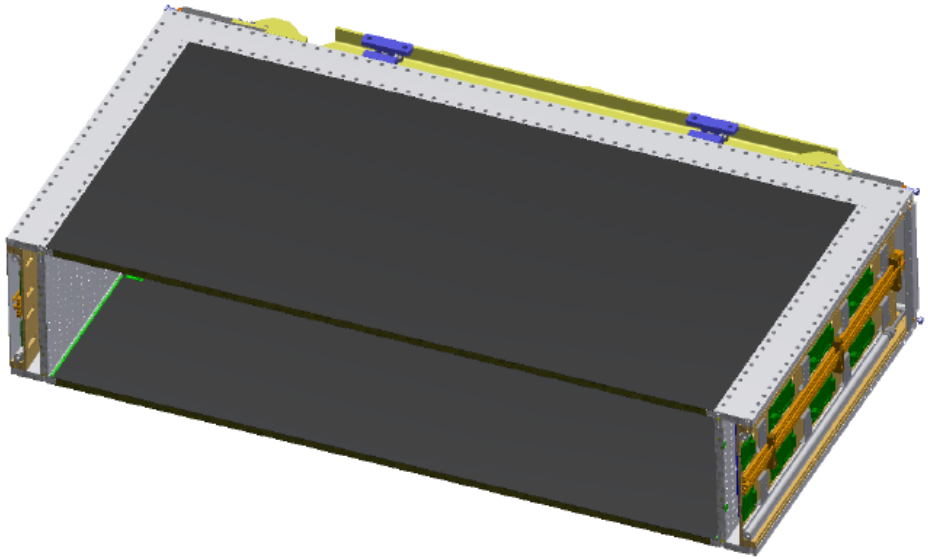
32 channel front end boards servicing array of 4 x 8 SiPMTs – the number of ECAL scintillator layers needs to be divisible by 4: 56 layers or 60 layers

Jan Boissevain

ECAL Readout Electronics Concept

Two pictures from a very nice step translation of the T2K downstream calorimeter model





Jan Boissevain

ECAL Geant 4 Simulation

Started a Geant 4 simulation to optimize the downstream electromagnetic calorimeter.

- **Stand-alone Geant4 (version 4.10.1) is used:**
  - Understand the containment of the electromagnetic shower originating from a 2.5 GeV electron or photon in the DS-ECAL.
  - Optimization of the detector geometry:
    - Width and thickness of each bar, alternate design to get the desired energy, position and time resolution.
    - Has significant impact on the cost: SiPM, readout electronics.
- **Geometry of the DS-ECAL is constructed in Geant4:**
  - 58 layers of alternating horizontal/vertical scintillator strips per 1.75 mm thick lead along the z-direction.
  - The standard scintillator bar dimensions of 4 m x 2.5 cm x 1 cm is used to start with.
  - Use particle gun to fire different particles such as electron, photon to the constructed detector.
  - Effort has just started in putting the ECAL Geant 4 simulation code in the ART framework.

◆ **Only one student working on it currently. More active participation from the collaboration is needed.**

ECAL Geant 4 Simulation

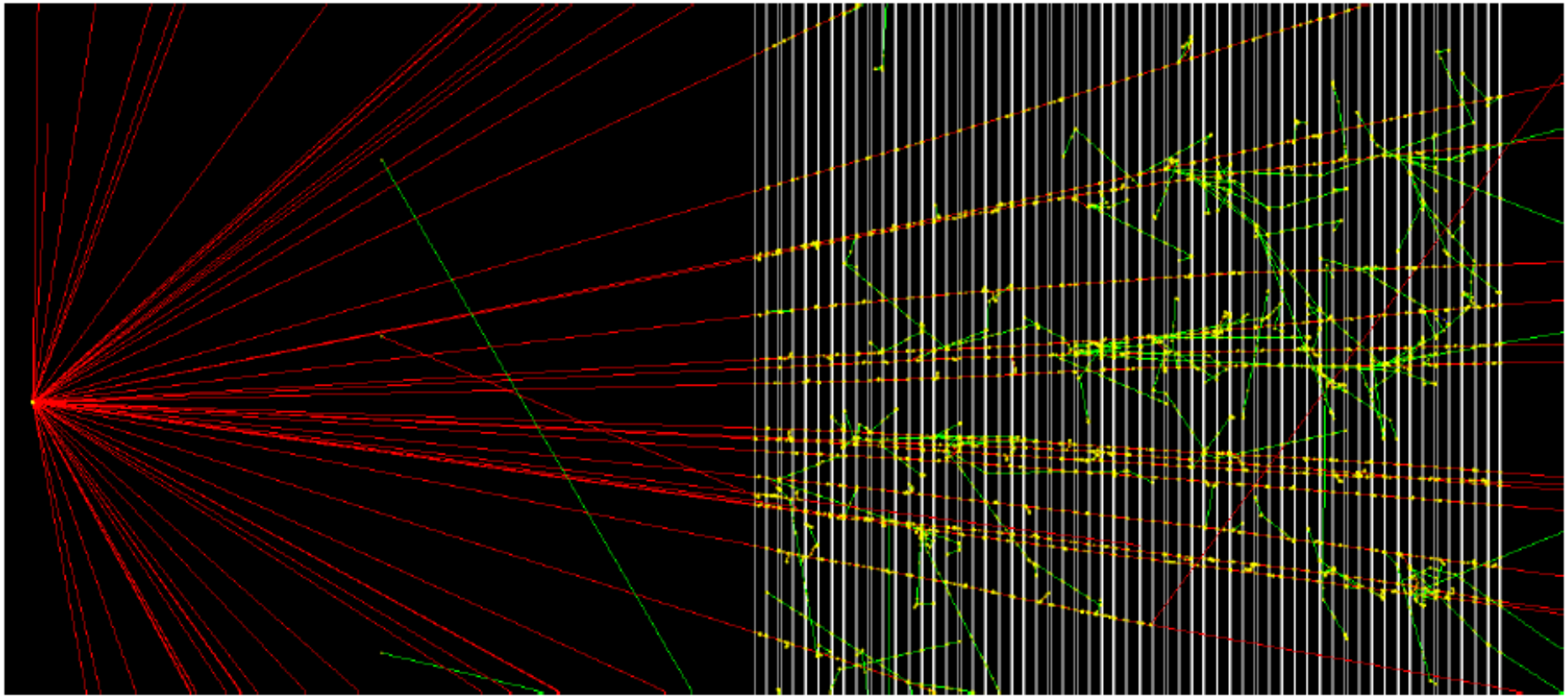


Figure : Longitudinal view of the electromagnetic shower in the Downstream ECAL by 2 GeV muons (10,000 events)

Soumya Ranjan Das

Summary

- **The R & D and prototyping plan for the ECAL is already developed. Need the go ahead from the funding agency/agencies.**
  - Immediate plan is to develop the infrastructure at IIT Guwahati for the detector assembly.
  - Focus on building the 2 m x 2 m downstream ECAL prototype in the next three years.
  - Initiated Geant 4 detector simulation for optimizing the ECAL geometry.

◆ **Discussion with JINR, Dubna for collaboration on the detector development.**

◆ **Participation from DUNE collaborating Institutions are welcome. Please join the effort**.